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(52) UK CL (Edition K)
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None

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Online databases: BIOSIS; EMBASE; MEDLINE; WPI

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(54) Detecting endoscope insertion direction

(57) The direction for further insertion of an endoscope on the basis of the form of a fold existing on the inside wall of part of a body cavity observed in an endoscope picture image. Discontinuous points are extracted from the endoscope image to form a further image, the further image is divided into a plurality of images, contour segments based on the discontinuous points are extracted from respective divided images, the contour segments obtained from the divided images are connected, the resulting line is considered to be the form of a fold, and the endoscope insertion direction is determined on the basis of this form of the fold. Extracting the discontinuous points may include extracting points at which the brightness or colour of the image varies. Extracting the contour segments may comprise of extracting the optimum contour segment from among a plurality of extracted candidates. A fibre optic endoscope with a curvable end section may be used.

FIG.1

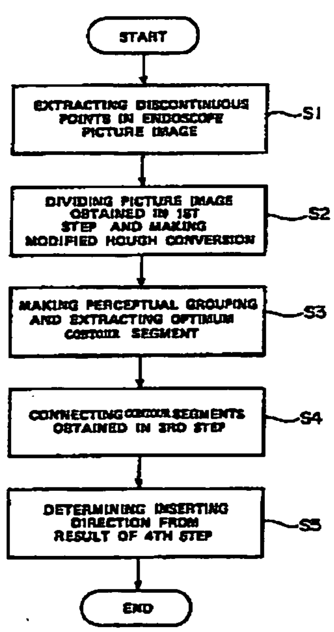

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FIG.1

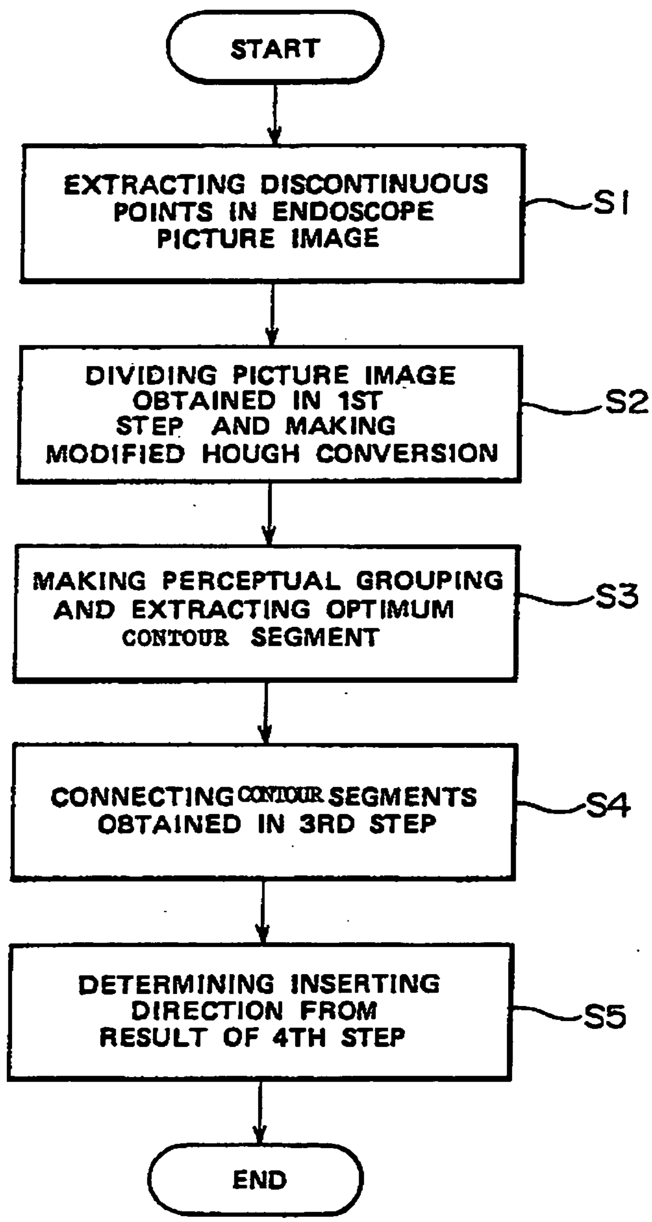

START
EXTRACTING DISCONTINUOUS POINTS IN ENDOSCOPE PICTURE IMAGE
S1
DIVIDING PICTURE IMAGE OBTAINED IN 1ST STEP AND MAKING MODIFIED HOUGH CONVERSION
S2
MAKING PERCEPTUAL GROUPING AND EXTRACTING OPTIMUM CONTOUR SEGMENT
S3
CONNECTING CONTOUR SEGMENTS OBTAINED IN 3RD STEP
S4
DETERMINING INSERTING DIRECTION FROM RESULT OF 4TH STEP
S5
END

FIG.2

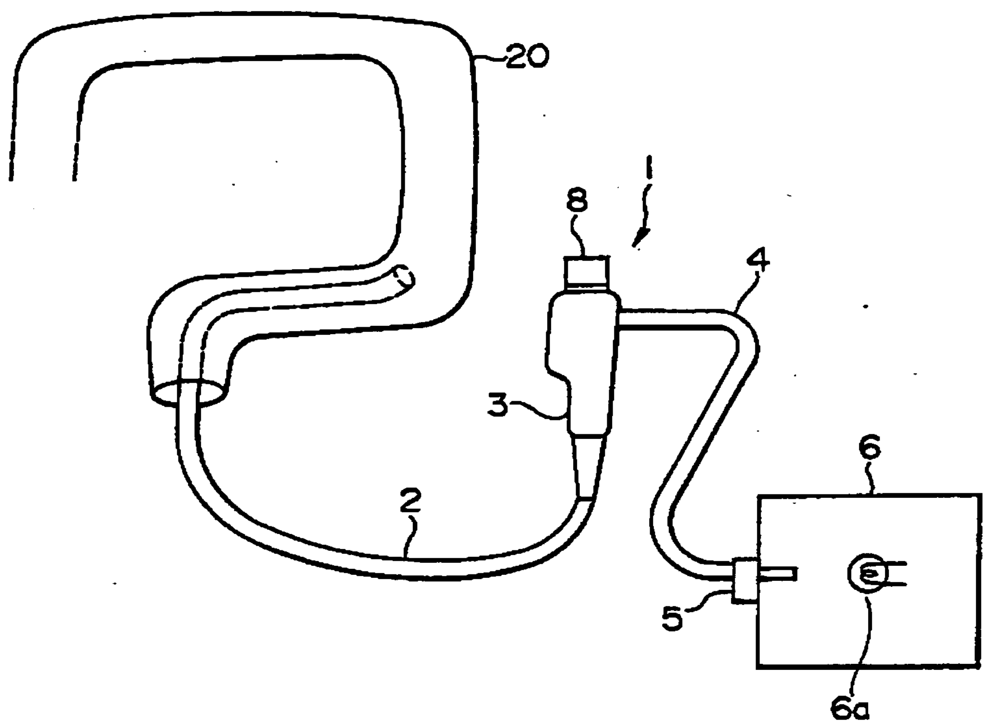


FIG.3

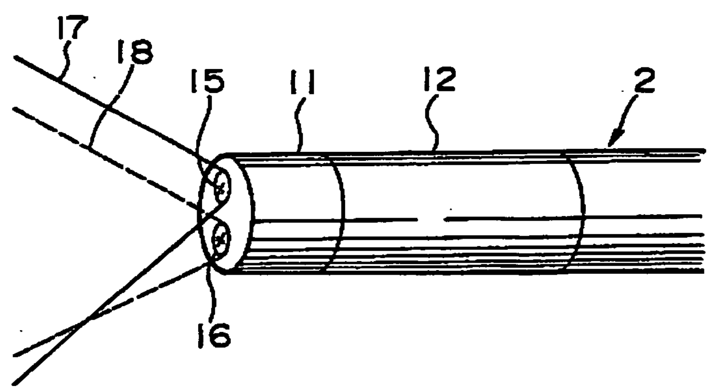


FIG.4

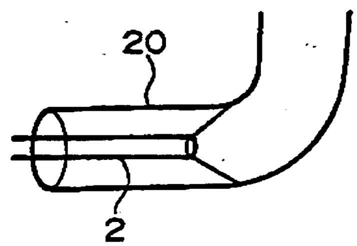


FIG.6

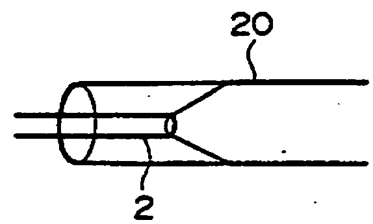


FIG.5

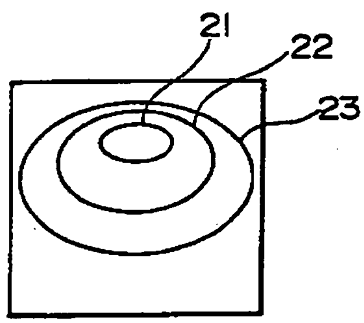


FIG.7

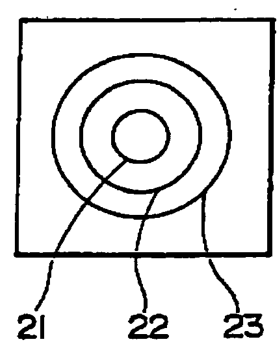


FIG. 8

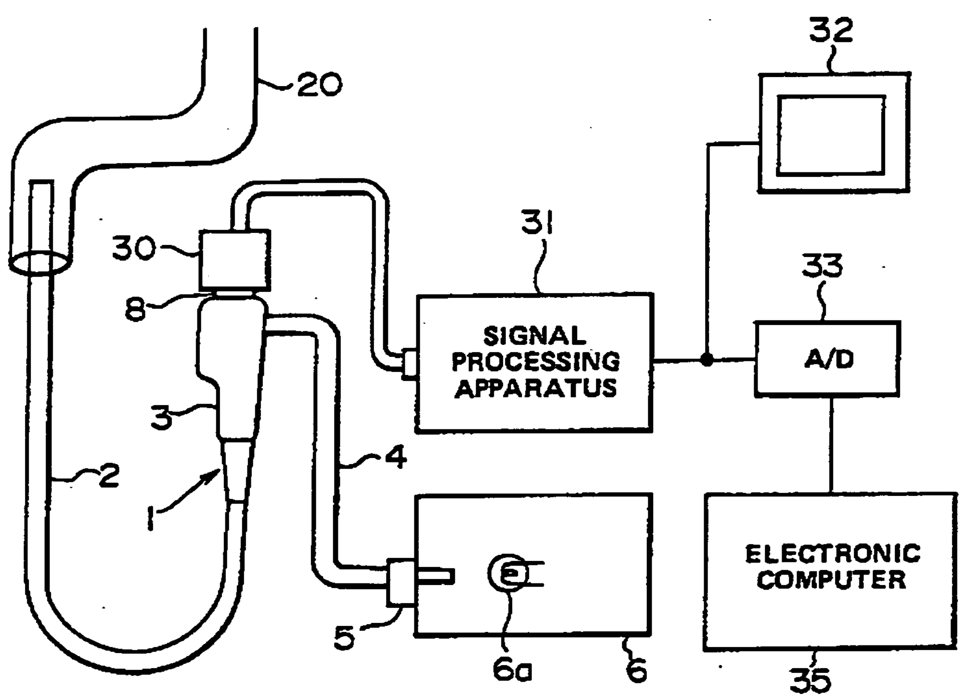

20
30
8
3
2
1
4
5
31
SIGNAL PROCESSING APPARATUS
6a
6
32
33
A/D
ELECTRONIC COMPUTER
35

FIG. 9

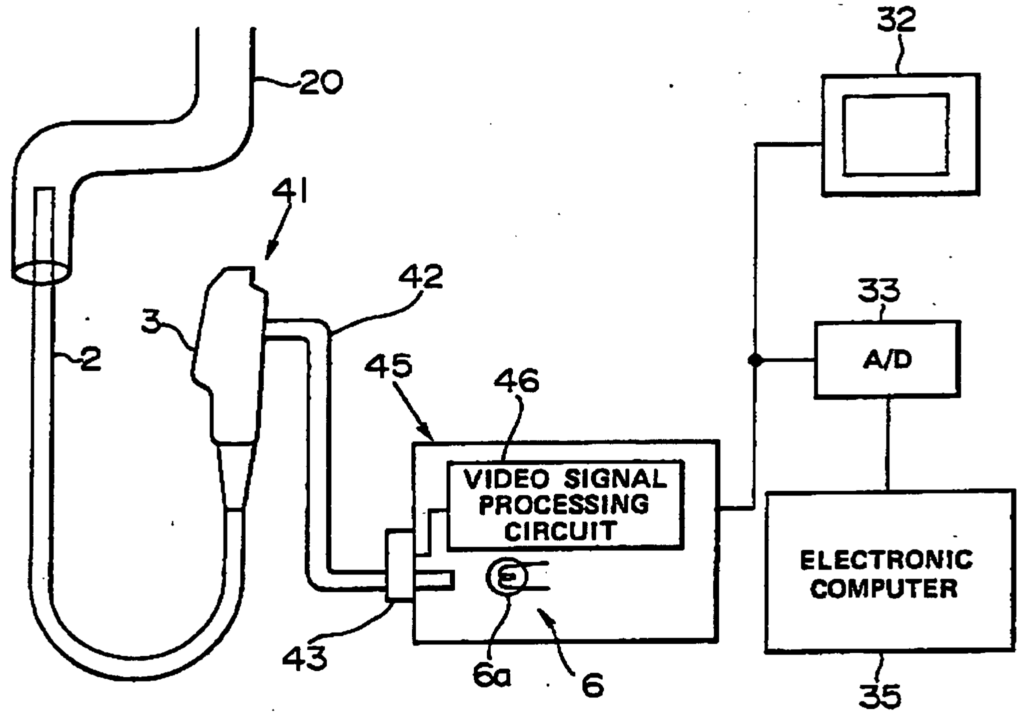

20
41
42
3
2
45
46
VIDEO SIGNAL PROCESSING CIRCUIT
43
6a
6
32
33
A/D
ELECTRONIC COMPUTER
35

FIG.10

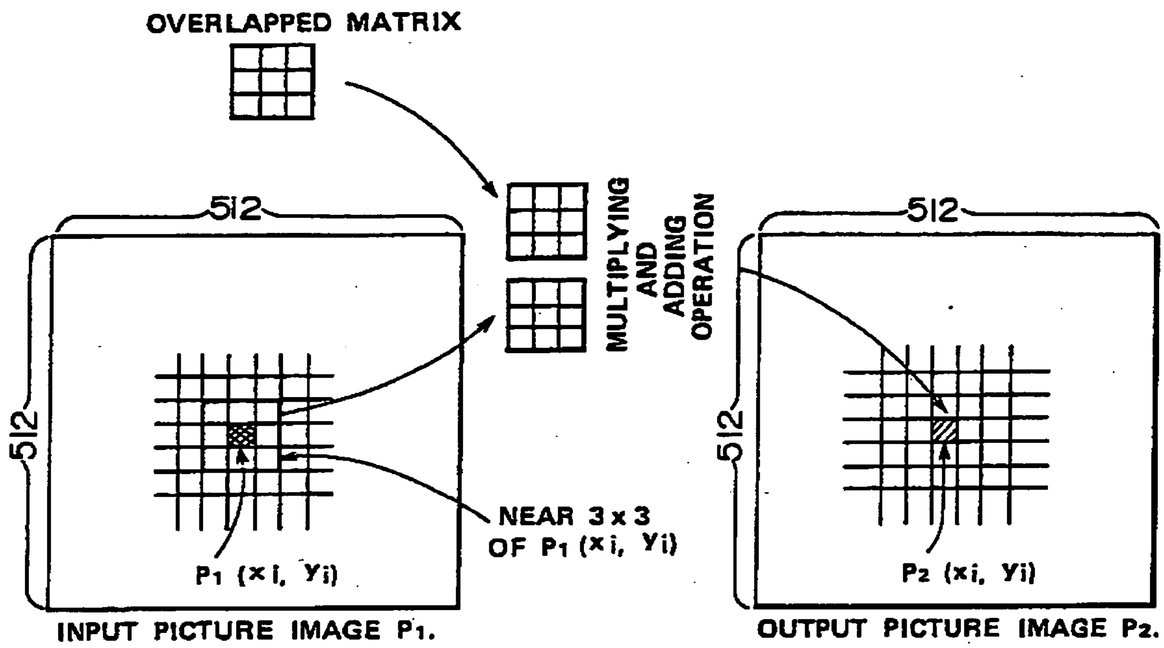


FIG.11(a)

−1	0	1
$-\sqrt{2}$	0	$\sqrt{2}$
−1	0	1

FIG.11(b)

1	$\sqrt{2}$	1
0	0	0
−1	$-\sqrt{2}$	−1

FIG.12

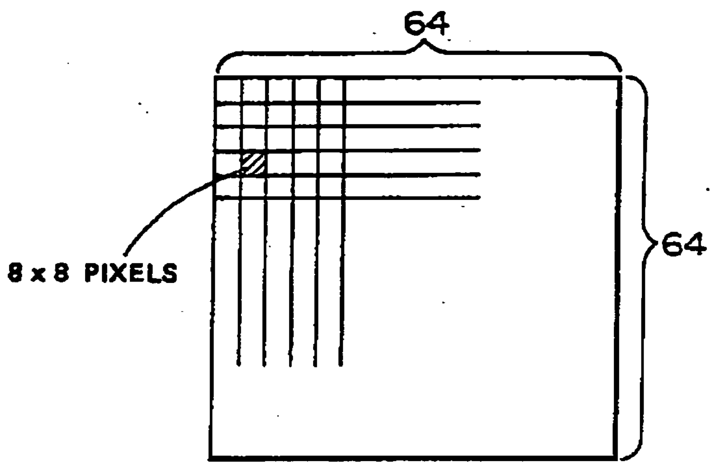


FIG.13

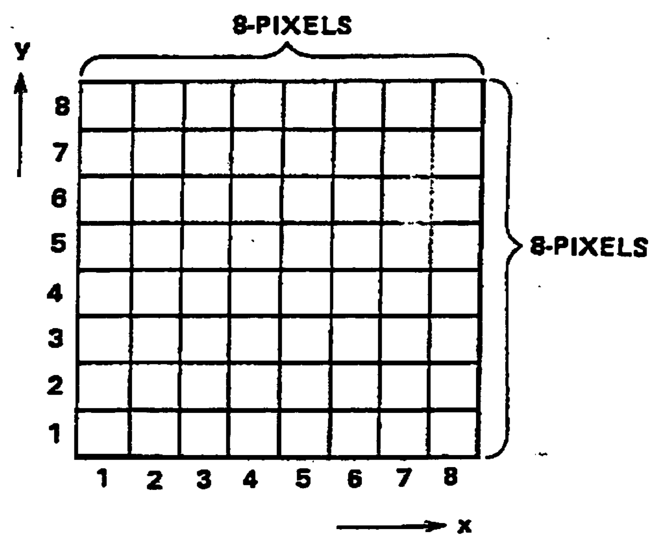


FIG.14

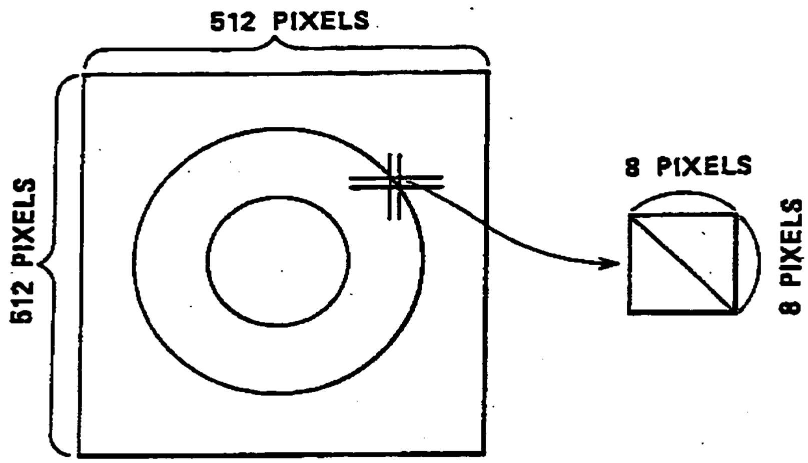


FIG.15

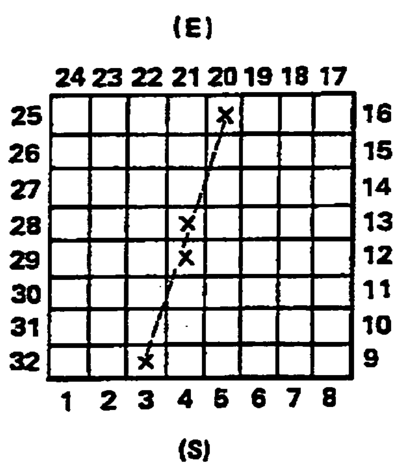


FIG.16

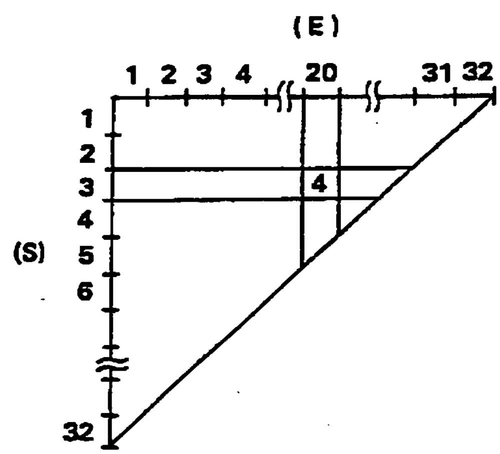


FIG.17

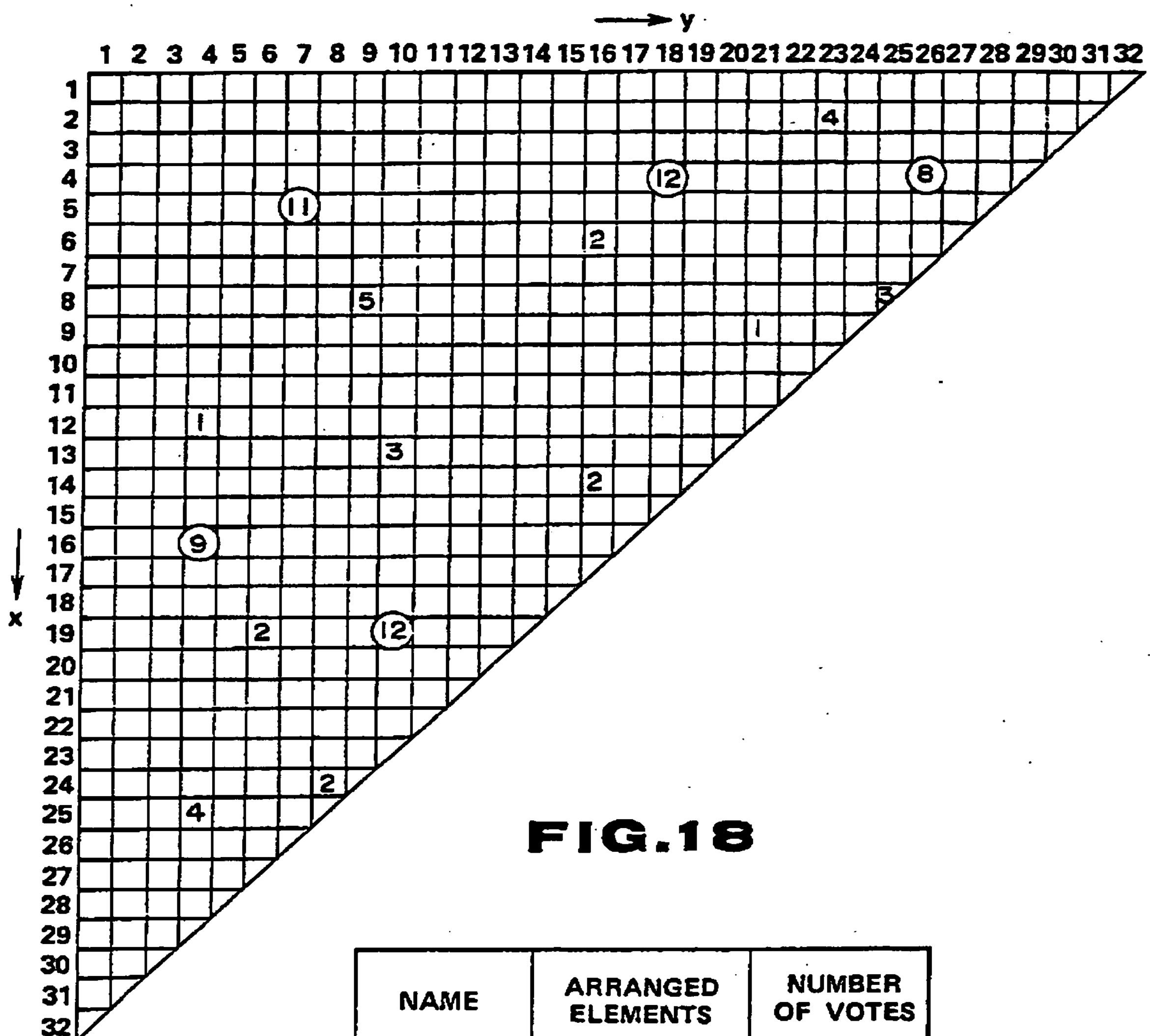
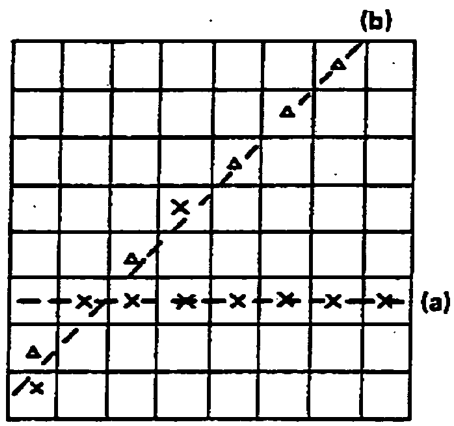


FIG.18

NAME	ARRANGED ELEMENTS	NUMBER OF VOTES
LINE 1	(4, 18)	12
" 2	(4, 26)	8
" 3	(5, 7)	11
" 4	(16, 4)	9
" 5	(19, 10)	12

FIG.19



Δ, × --- EDGE POINT

(Δ -----EDGE POINT
BY NOISE)

FIG.20

EXAMPLE

$$\theta = \left.\begin{array}{r} 5^\circ \\ 8^\circ \\ 20^\circ \\ 21^\circ \\ 22^\circ \\ 23^\circ \\ 29^\circ \\ 35^\circ \end{array}\right\} \text{GROUP 1}$$

$$62^\circ \text{ ----- GROUP 2}$$

FIG.21

EXAMPLE

(1,8)
(1,7)
(2,7)
(2,6)
(2,4) ← Δy > 1
(3,4)
(3,3)
(3,2)
(3,1)
(4,1)

FIG.22

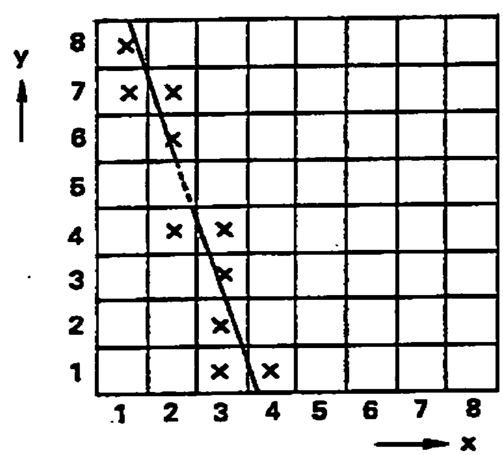


FIG.23

POINT	CONTINUITY	GREY LEVEL	EDGE ORI.	GROUP
1	GROUP 1	GROUP a	GROUP α	A
2	" 1	" a	" α	A
3	" 1	" a	" α	A
4	" 1	" a	" α	A
5	" 1	" a	" α	A
6	" 1	" a	" α	A
7	" 1	" b	" α	B
8	" 1	" b	" α	B
9	" 2	" b	" α	C
10	" 3	" a	" β	D
11	" 4	" c	" β	E
12	" 4	" c	" γ	F

FIG.24

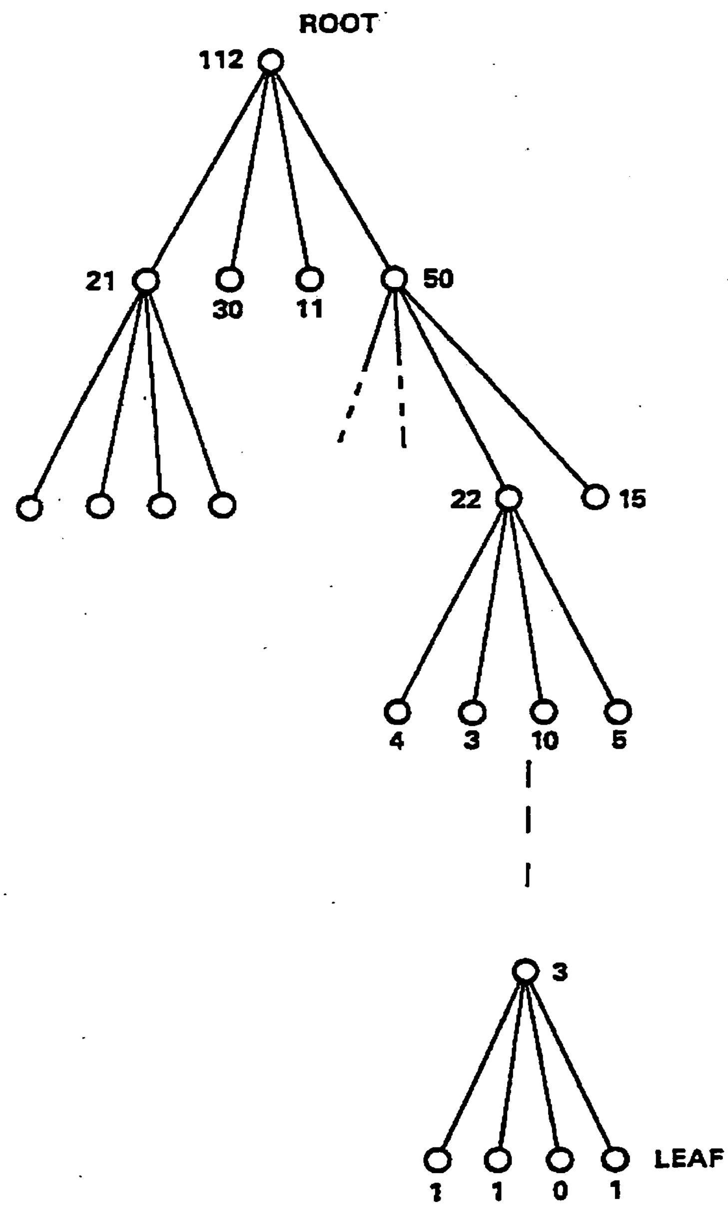


FIG.25

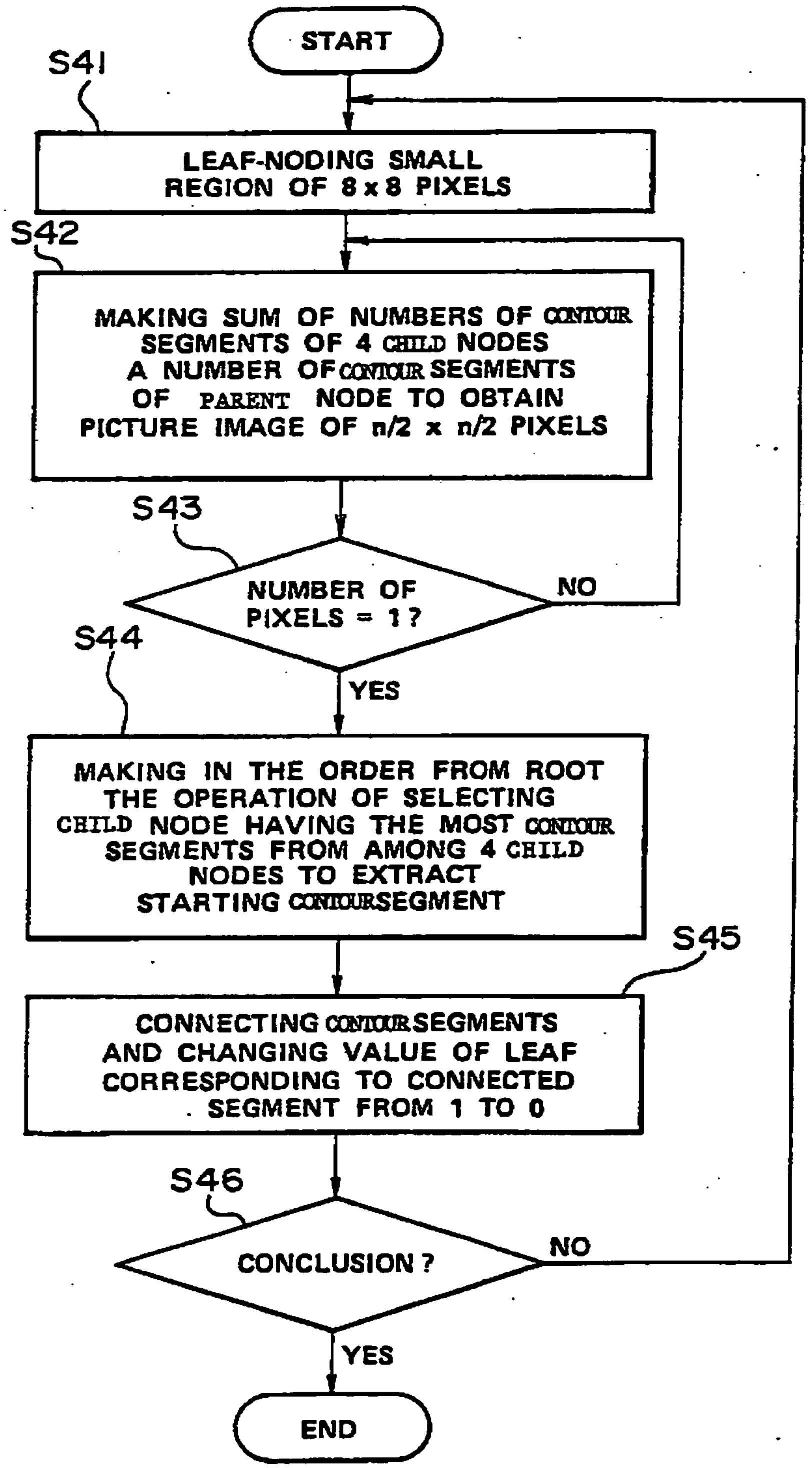

START
S41
LEAF-NODING SMALL REGION OF 8 x 8 PIXELS
S42
MAKING SUM OF NUMBERS OF CONTOUR SEGMENTS OF 4 CHILD NODES A NUMBER OF CONTOUR SEGMENTS OF PARENT NODE TO OBTAIN PICTURE IMAGE OF n/2 x n/2 PIXELS
S43
NUMBER OF PIXELS = 1 ?
NO
YES
S44
MAKING IN THE ORDER FROM ROOT THE OPERATION OF SELECTING CHILD NODE HAVING THE MOST CONTOUR SEGMENTS FROM AMONG 4 CHILD NODES TO EXTRACT STARTING CONTOUR SEGMENT
S45
CONNECTING CONTOUR SEGMENTS AND CHANGING VALUE OF LEAF CORRESPONDING TO CONNECTED SEGMENT FROM 1 TO 0
S46
CONCLUSION ?
NO
YES
END

FIG.26(a)

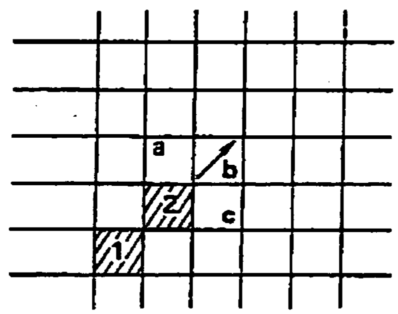


FIG.26(b)

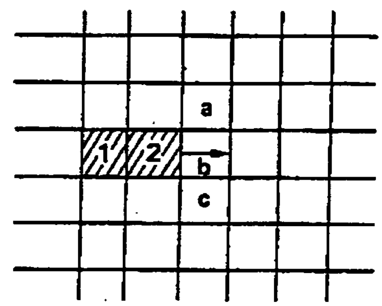


FIG.26(c)

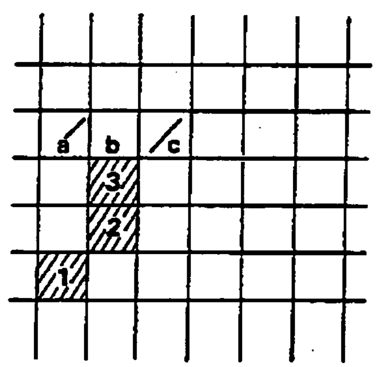


FIG.26(d)

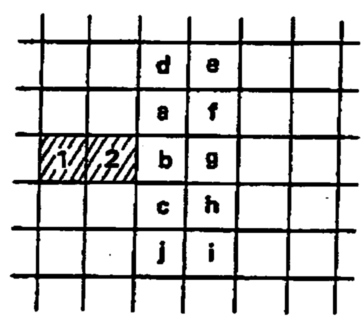


FIG.27(a)

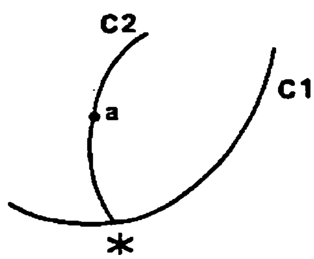


FIG.27(b)

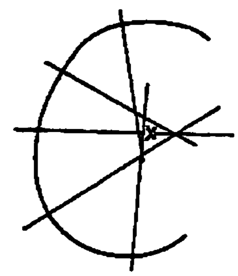


FIG.27(c)

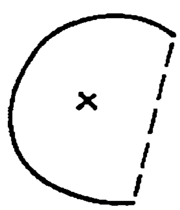


FIG.27(d)

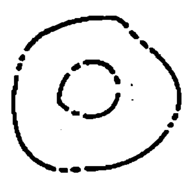


FIG.28

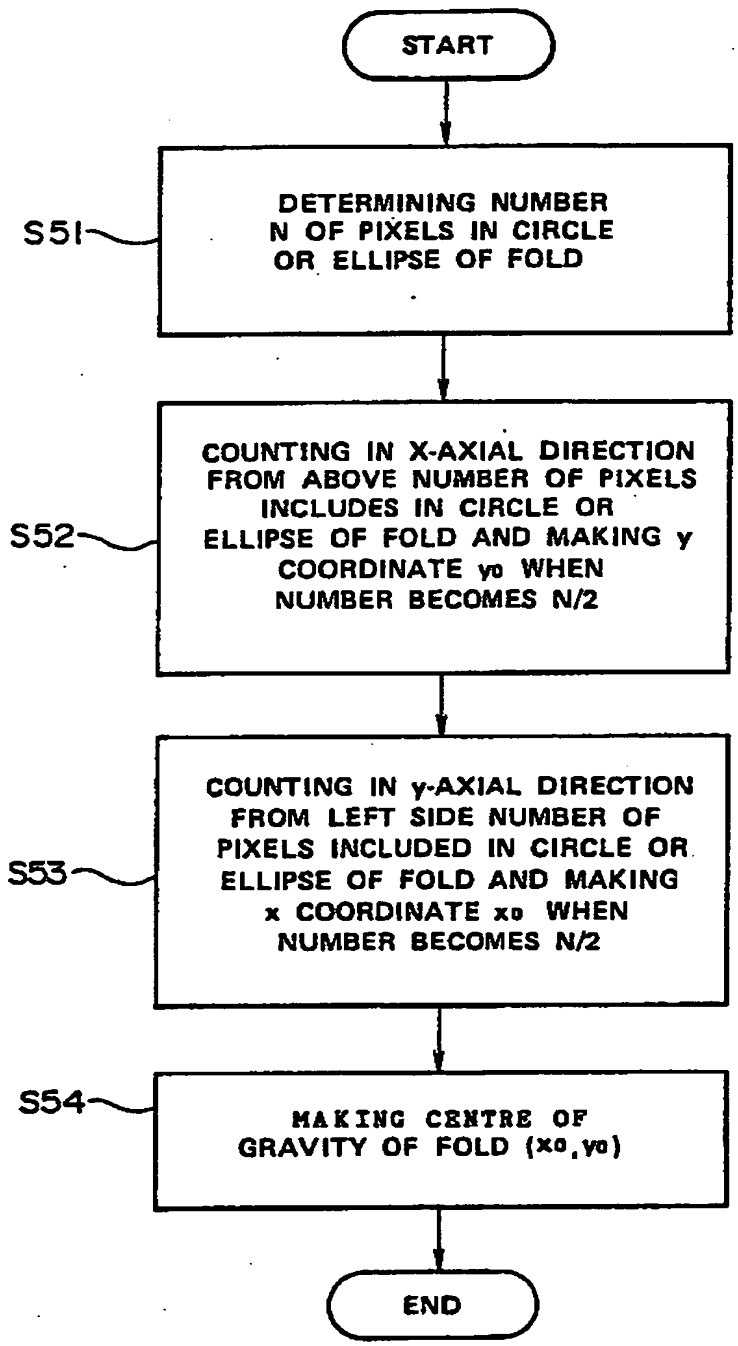

START
S51
DETERMINING NUMBER N OF PIXELS IN CIRCLE OR ELLIPSE OF FOLD
S52
COUNTING IN X-AXIAL DIRECTION FROM ABOVE NUMBER OF PIXELS INCLUDES IN CIRCLE OR ELLIPSE OF FOLD AND MAKING y COORDINATE y0 WHEN NUMBER BECOMES N/2
S53
COUNTING IN y-AXIAL DIRECTION FROM LEFT SIDE NUMBER OF PIXELS INCLUDED IN CIRCLE OR ELLIPSE OF FOLD AND MAKING x COORDINATE x0 WHEN NUMBER BECOMES N/2
S54
MAKING CENTRE OF GRAVITY OF FOLD (x0,y0)
END

FIG.29

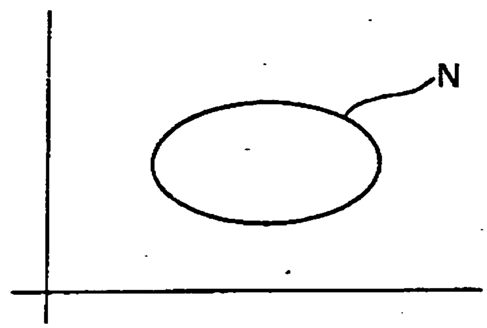


FIG.30

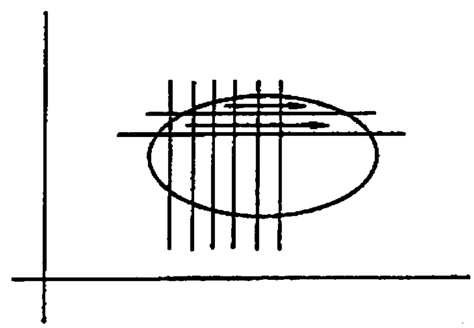


FIG.31

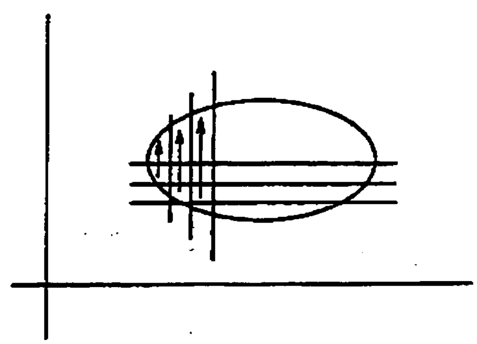


FIG.32

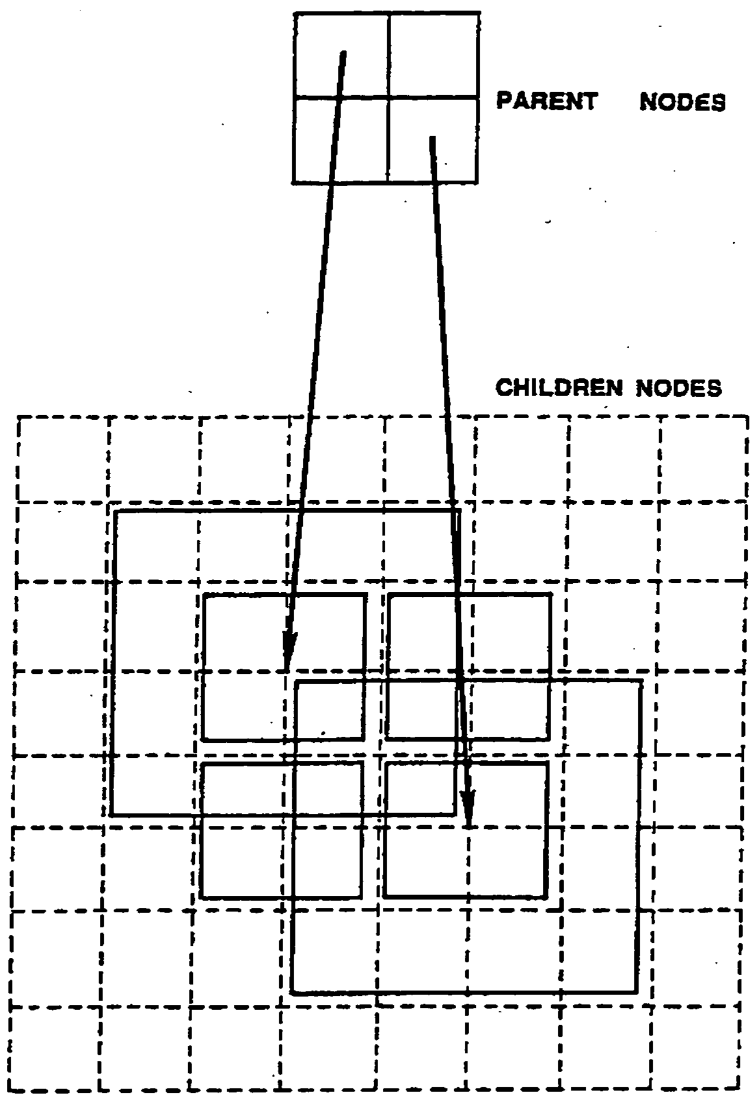


FIG.33

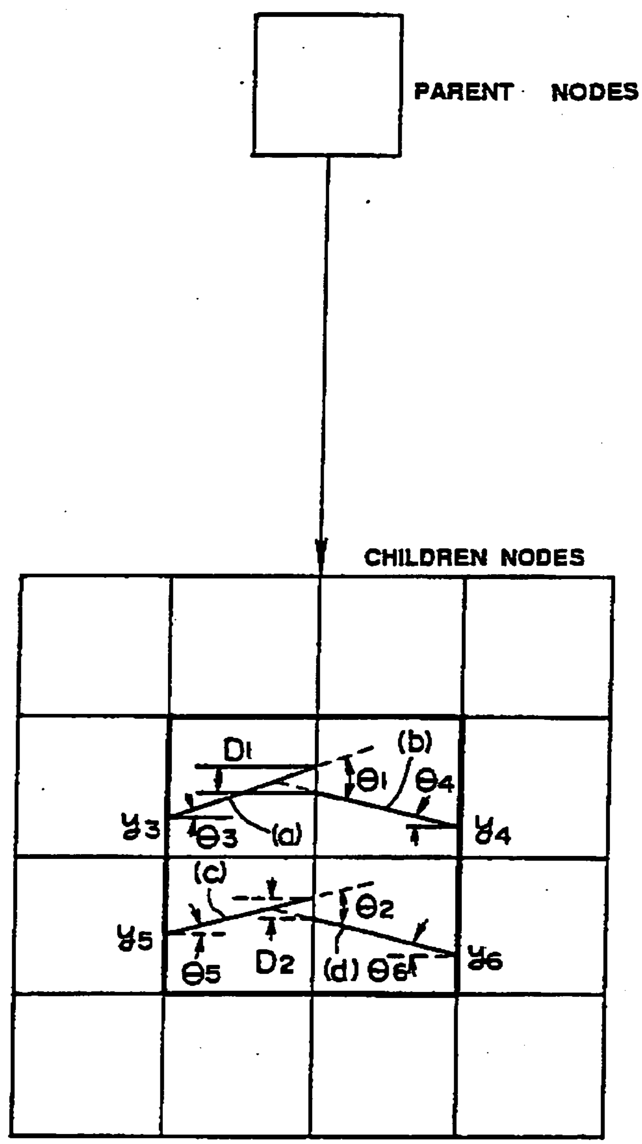
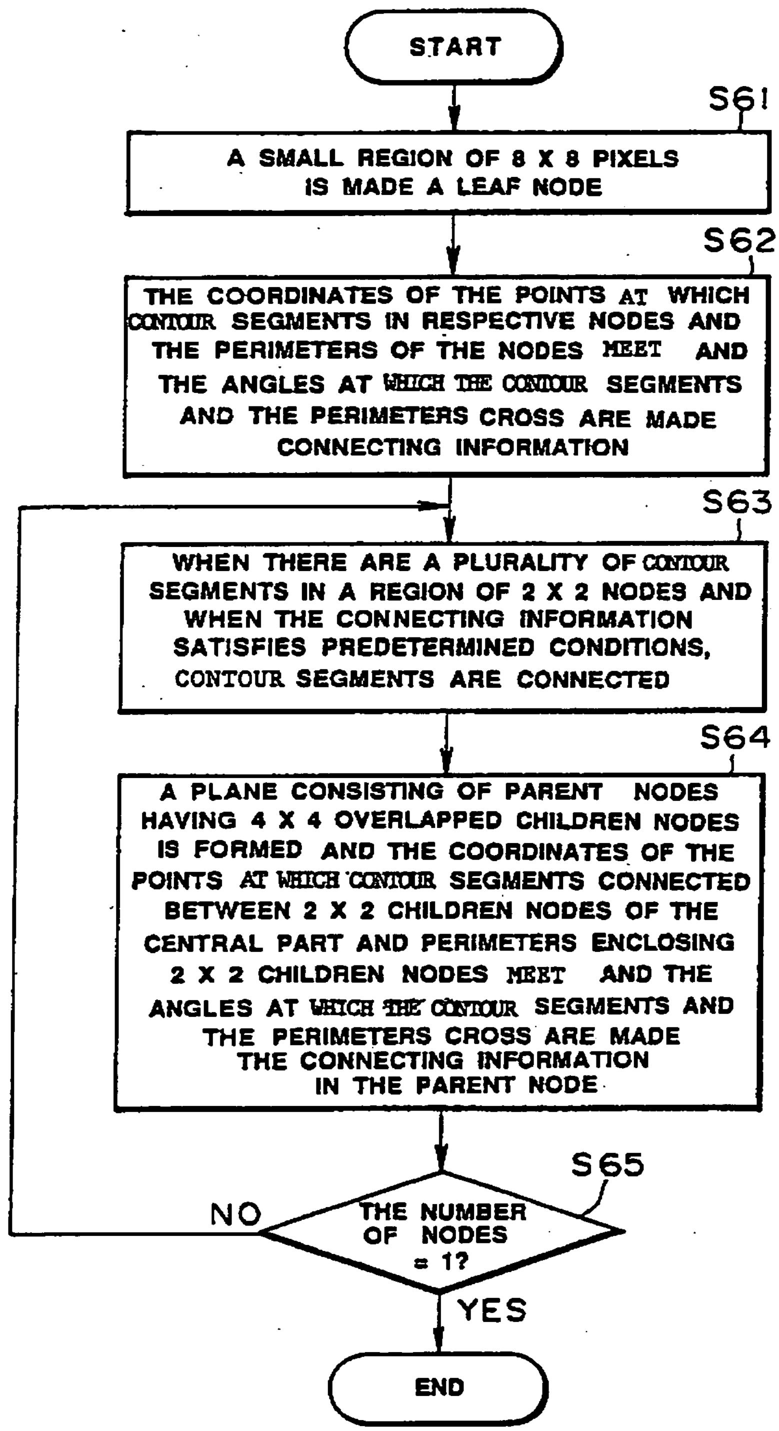

PARENT NODES
CHILDREN NODES
D1
(b)
θ1
θ4
y3
θ3
(a)
y4
(c)
θ2
y5
θ5
D2
(d) θ6
y6

FIG. 34


START
S61
A SMALL REGION OF 8 X 8 PIXELS IS MADE A LEAF NODE
S62
THE COORDINATES OF THE POINTS AT WHICH CONTOUR SEGMENTS IN RESPECTIVE NODES AND THE PERIMETERS OF THE NODES MEET AND THE ANGLES AT WHICH THE CONTOUR SEGMENTS AND THE PERIMETERS CROSS ARE MADE CONNECTING INFORMATION
S63
WHEN THERE ARE A PLURALITY OF CONTOUR SEGMENTS IN A REGION OF 2 X 2 NODES AND WHEN THE CONNECTING INFORMATION SATISFIES PREDETERMINED CONDITIONS, CONTOUR SEGMENTS ARE CONNECTED
S64
A PLANE CONSISTING OF PARENT NODES HAVING 4 X 4 OVERLAPPED CHILDREN NODES IS FORMED AND THE COORDINATES OF THE POINTS AT WHICH CONTOUR SEGMENTS CONNECTED BETWEEN 2 X 2 CHILDREN NODES OF THE CENTRAL PART AND PERIMETERS ENCLOSING 2 X 2 CHILDREN NODES MEET AND THE ANGLES AT WHICH THE CONTOUR SEGMENTS AND THE PERIMETERS CROSS ARE MADE THE CONNECTING INFORMATION IN THE PARENT NODE
S65
THE NUMBER OF NODES = 1?
NO
YES
END

METHODS OF DETECTING ENDOSCOPE INSERTION DIRECTION:

This invention relates to methods of detecting the requisite direction of insertion of an endoscope, and more particularly to an endoscope insertion direction detecting method adapted to automatically aid the insertion of an endoscope in the large intestine, to facilitate medical inspection.

Recently, there has been extensive use of an endoscope whereby organs within a body cavity can be observed by inserting an elongate insertion sheath into the body cavity and various curing treatments can be made by using treatment tools, inserted through the sheath in a treating tool channel, as required.

In a conventional endoscope inspection, the doctor judges the required direction for advance of the endoscope insertion sheath by observing the endoscope image, while inserting the endoscope.

However, high levels of technique and skill are required to insert an endoscope in inspecting the large intestine.

One object of the present invention is to provide an endoscope insertion direction detecting method whereby the endoscope insertion direction can be simply and quickly detected, whilst the adverse influence of noise can be reduced, enabling the appropriate endoscope insertion direction to be detected more accurately.

In accordance with the present invention a method of detecting a required endoscope insertion direction includes extracting the form of a fold existing on the inside wall of an observed part from an endoscope picture image and to judge the endoscope insertion direction on the basis of the form of the fold extracted by this step. It comprises, for example, a step of extracting discontinuous points at which the brightness or colour in an endoscope picture image varies.

Advantageously, after extracting said discontinuous points, the invention comprises the further steps of extracting contour segments based on said discontinuous points from respective divided picture images obtained by dividing the picture image obtained by the above-mentioned step of extracting the discontinuous points into a plurality of picture images, a step of connecting the contour segments obtained by the above-mentioned step of extracting the contour segments, and a step of considering the line connected by the above-mentioned connecting step to be the form of a fold existing on the inside wall of the observed part and judging the endoscope insertion direction on the basis of this form of the fold. The above-mentioned step of extracting the discontinuous points determines the degree to which the brightness of the picture image varies. The above-mentioned step of extracting the contour segments has, for example, a step of extracting contour segment candidates and a further step of extracting the optimum contour segment from among those candidates. For example, the above-mentioned step of extracting the candidates includes using a modified Hough transformation in extracting the contour segments.

The above-mentioned step of extracting the optimum contour segment includes making a perceptual grouping to extract the optimum contour segment. The above-mentioned connecting step includes, for example, extracting a search starting contour segment by utilising a pyramid quad tree structure.

The invention will now be described with reference to the drawings, in which:-

Figure 1 is a flow chart showing the steps of one exemplary method in accordance with the present invention;

Figure 2 is an explanatory view representing the insertion sheath of an endoscope entering into the large intestine;

Figure 3 is a perspective view showing the tip of the endoscope insertion sheath;

Figure 4 is an explanatory view showing the insertion sheath of an endoscope advancing into a bent part of the large intestine;

Figure 5 is an explanatory view showing the endoscope image obtained when in the state shown in Figure 4;

Figure 6 is an explanatory view showing the insertion sheath of an endoscope entering into a straight part of the large intestine;

Figure 7 is an explanatory view showing the endoscope image obtained when in the state shown in Figure 6;

Figure 8 is an explanatory view showing an example of a suitable endoscope apparatus, using a fibre-scope and externally fitted television camera;

Figure 9 is an explanatory view showing an example of a suitable endoscope apparatus using a video-scope;

Figure 10 is a view for explaining the use of a spatial filtering in the first step;

Figure 11(a) is an explanatory view showing an overlapped matrix determining a gradient in an x-direction, and

Figure 11(b) is an explanatory view showing an overlapped matrix determining a gradient in a y-direction;

Figure 12 is an explanatory view showing an exemplary picture image, as obtained in the first step, when divided into small squares of 8 x 8 pixels;

Figure 13 is an explanatory view showing a small square of 8 x 8 pixels;

Figure 14 is an explanatory view showing a contour segment

of a fold located in a small region of 8 x 8 pixels;

Figure 15 is an explanatory view showing a small square of 8 x 8 pixels with addresses applied around the outer periphery to make a modified Hough transformation;

Figure 16 is an explanatory view showing arranged elements obtained by a modified Hough conversion of straight lines;

Figure 17 is an explanatory view showing arranged elements obtained by modified Hough conversion of straight lines and an example of a number of edge points located on straight lines corresponding to the respective arranged elements;

Figure 18 is a table showing straight lines of a large number of edge points;

Figure 19 is an explanatory view showing contour segments within a small square;

Figure 20 is a table showing grouping by an edge orientation;

Figure 21 is a table showing grouping by a continuity;

Figure 22 is an explanatory view showing edge points on a small square for explaining grouping by a continuity;

Figure 23 is a table showing an example of a result of a perceptual grouping;

Figure 24 is an explanatory view showing a pyramid quad tree structure;

Figure 25 is a partial flow chart showing details of the fourth step;

Figures 26(a) to (d) are explanatory views showing small squares to be searched next in the case of connecting contour segments;

Figures 27(a) to (d) are explanatory views showing a method of determining an insertion direction from the form of a fold;

Figure 28 is a partial flow chart showing a step of determining the centre of gravity of a ring;

Figure 29 is an explanatory view showing an ellipse of a fold;

Figure 30 is an explanatory view showing a step of determining an x-coordinate of the centre of gravity of a ring; and

Figure 31 is an explanatory view showing a step of determining a y-coordinate of the centre of gravity of a ring.

Figures 32 to 34 relate to the second embodiment of the present invention.

Figure 32 is an explanatory view showing a part of an overlapped pyramid structure.

Figure 33 is an explanatory view showing a connection of contour segments in an overlapped pyramid structure.

Figure 34 is a flow chart showing the fourth step of the embodiment.

First of all, a summary of the present invention will be given by way of explanation with reference to Figures 2 to 7.

As shown in Figure 2, an endoscope 1 of the fibre-scope type is provided with an elongated flexible insertion sheath 2 connected to extend from the rear of a thick operating part 3. A flexible optical cable 4 extends from a side-port of the operating part 3 and is provided at its end with a connector 5, which can be connected to a light output port of an illuminating source 6 containing a lamp 6a. The operating part 3 is provided at its rear end with an eye-piece 8.

As shown in Figure 3, a rigid tip 11 is supported on a curvable section 12 provided at the remote end of the insertion sheath 2. The operating part 3 is provided with a curvature control operating knob (not illustrated) so that the curvable section 12 may be curved vertically and/or horizontally, as required, by operation of this curvature control operating knob.

An illuminating lens 15 of an illuminating optical system and an objective lens 16 of an observation optical system are arranged in the sheath end-face directed substantially in the same direction as the axis of the rigid tip 11. A light guide (not illustrated), for example an optical fibre bundle, is provided in

the sheath 2 at the rear of the illuminating lens 15. This light guide is inserted through the insertion sheath 2, operating part 3 and optical cable 4, and is connected to the connector 5 so that, when this connector 5 is coupled to the light source 6, the illuminating light emitted by the lamp 6a enters the light guide, to be led to the tip 11 and emitted from the tip end-face to be radiated out to an object through the illuminating lens 15, as indicated in Figure 3 by solid lines 17 representing the illuminated region.

The end-face of an image-relaying fibre bundle (not illustrated) is arranged in the image-forming plane of the objective lens 16. This image guide is inserted through the insertion sheath 2 and extends to the eye-piece 8. The object image formed by the objective lens 16 will be led to the eye-piece 8 so that it can be observed through the eye-piece lens (not shown), which is mounted in the eye-piece 8. In Figure 3, a pair of broken lines 18 indicate the visual field of the observing optical system.

Now, as shown in Figure 3, the illuminating optical system and observing optical system of the endoscope 1 are adjacent to each other and are directed substantially in the same direction.

On the other hand, annular folds, also called haustras, exist on the inside wall of the large intestine. Most endoscope doctors judge the endoscope insertion direction by the manner in which such an annular fold is seen. That is to say, the centre of the ring of such fold is an excellent criterion in judging the endoscope insertion direction. This shall be explained with reference to Figures 4 to 7.

In Figures 5 and 7, folds 21 and 22 are represented on the inside wall of the large intestine.

Figure 4 shows the case when inserting the insertion sheath 2 of the endoscope 1 into an upwardly bent part of the large intestine. In such a case, as shown in Figure 5, the folds are seen as being upwardly deviated. Therefore, in this case, the tip 11 of the endoscope 1 should be curved upward and the insertion sheath 2 will then be inserted to move upwardly.

Figure 6 shows the case of inserting the insertion sheath 2 of the endoscope 1 into a straight part of the large intestine 20. In this case, as shown in Figure 7, the folds are seen with no deviation, vertically or horizontally. Therefore, in this case, the insertion sheath 2 of the endoscope 1 may be inserted in its straight condition.

Thus, in the proposed methods of endoscope insertion direction detection, the form of the folds existing on the inside wall, as seen in the endoscope image, is extracted and the endoscope insertion direction is deduced on the basis of the form of these folds.

This embodiment of an endoscope insertion direction detecting method can be employed with endoscopes such as are shown, for example, in Figure 8 or Figure 9.

The endoscope apparatus shown in Figure 8 is provided with a fibre-scope 1 fed with illuminating light by a light source 6, and an externally fitted television camera 30 is fitted to the eye-piece 8 of this fibre-scope 1. The construction of the fibre-scope 1 is the same as that shown in Figure 2 and need not be

further explained here. The externally fitted television camera 30 is provided, for example, with an image lens (not illustrated) that forms an image of light from the eye-piece 8 and utilises a solid state imaging device (not illustrated), arranged in the image plane of this image-forming lens. This externally fitted television camera 30 drives the solid state imaging device and is connected to a signal processing apparatus 31 to convert the output signal of this solid state imaging device to form a video signal. The video signal output of the signal processing apparatus 31 is fed into a monitor 32, and also converted to digital form by an A/D-converter 33, which then feeds into an electronic computer 35, and can be taken into a memory (not illustrated) within this electronic computer 35. The endoscope image will be displayed on the monitor 32, and the endoscope insertion direction detecting method in this embodiment can be carried out by the electronic computer 35.

The endoscope apparatus shown in Figure 9 is provided with a video-scope 41 instead of a fibre-scope 1 and externally fitted television camera 30. As with the fibre-scope 1, this video-scope 41 is provided with an elongate flexible insertion sheath 2 and an operating part 3 connected to the rear of this insertion sheath 2. A flexible optical cable 42 extends sidewise from the operating part 3 and is provided at its end with a connector 43 which is connected to a control apparatus 45 containing a light source 6 and a video signal processing circuit 46. A solid state imaging device (not illustrated) is arranged in the image forming position of the objective lens in the tip of the insertion sheath 2 of the video-scope 41 and is

connected to a video signal processing circuit 46 within the control apparatus 45 through the signal lines inserted through the insertion sheath 2, operating part 3, cable 42 and connector 43. The illuminating optical system of the video-scope 41 is the same as that of the fibre-scope 1, in that the illuminating light emitted from the lamp 6a of the light source 6 within the control apparatus 45 may enter the light guide at the entrance end. The solid state imaging device will be driven by the video signal processing circuit 46, and the output signal of this solid state imaging device will be processed to form a video signal by the video signal processing circuit. As in the endoscope apparatus using the fibre-scope 1, the video signal output from this signal processing circuit 46 can be fed into the monitor 32, and can be converted to digital form by the A/D-converter 33, to be input into the electronic computer 35 and taken into the memory (not illustrated) within this electronic computer 35. The endoscope image will be displayed on the monitor 32 and the endoscope insertion direction detecting method in this embodiment will be carried out by the electronic computer 35.

The endoscope insertion direction detecting method utilised in this embodiment will be further explained in the following, with reference to Figure 1.

As indicated in the flow chart shown in Figure 1, this direction detecting method comprises a first step S1, extracting discontinuous points in an original image fed into the electronic computer 35, a second step S2 dividing the picture image obtained in the first step S1 into a plurality of picture images and extracting contour segment candidates by using a modified Hough conversion from each of the divided picture images, a third step S3

making perceptual grouping of the contour segment candidates obtained in the second step and extracting the optimum contour segment from each of the divided picture images, a fourth step S4 connecting the contour segments obtained in the third step S3, and a fifth step S5 for determining the insertion direction from the result of the

fourth step S4.

The first step will be explained with reference to Figures 10, 11a and 11b.

In extracting discontinuous points, a colour defined by red, green and blue values may be noted, or a grey level (thickness or brightness). In this embodiment, the case of noting a grey level will be explained. The number of pixels of the original picture shall be 512 x 512 and the grey level shall be of 256 gradations.

Extracting discontinuous points by noting a grey level is achieved by inspecting the variation rate (gradient) of the grey level on a spatial coordinate, and extracting the grey level in the variation. This is an edge detection by noting the grey level.

For the edge detecting, for example, spatial filtering using a overlapped matrix is used in this embodiment.

Spatial filtering for the case using an overlapped matrix consisting of 3 x 3 pixels will be explained with reference to Figure 10. In Figure 10, P_1 (x_i,y_i) represents the grey level of the pixel of an input picture image P_1 having a coordinate (x_i,y_i). In the same manner, P_2 (x_i,y_i) represents the gradient of the picture image of coordinate (x_i,y_i) in an output picture image P_2.

First of all, the locality of 3 x 3 in the input picture image P_1 (x_i, y_i) is taken out, a product of the value of each pixel in this local zone of 3 x 3 calculated, and the value of each element corresponding to the overlapped matrix consisting of separately prepared 3 x 3 elements is calculated, to determine a sum of 9 products for the zone P_2 (x_i, y_i) in the output picture image.

This operation is repeated in turn for the respective pixels of the input picture image to obtain an output picture image P_2 to which spatial filtering has been applied.

Now, a gradient (grey level variation rate) g_x in the x-direction is obtained by using an overlapped matrix as shown in Figure 11(a). In the same manner, a gradient (grey level variation rate) g_y in the y-direction is obtained by using an overlapped matrix as shown in Figure 11(b). An absolute value of the gradient in a pixel is given by the under-mentioned formula (1-1) but, in this embodiment, the absolute value need not be very accurate and therefore, for brevity in the operation, it may be approximated by a formula (1-2) as follows:-

$$g = gx^2 + gy^2 \qquad (1\text{-}1).$$

$$g = |gx| + |gy| \qquad (1\text{-}2).$$

where g represents the magnitude of the discontinuity.

For the pixel of the coordinate (x_i, y_i) in the case of the overlapped matrices shown in Figures 11(a) and 11(b), g_x and g_y are used, and are given in concrete terms by the following formulae, (1-3) and (1-4):-

$$
\begin{aligned}
g_x &= P_2 (x_i, y_i) \\
&= -P_1 (x_i - 1, y_i + 1) \\
&\quad +P_1 (x_i + 1, y_i + 1) \\
&\quad -\sqrt{2} \cdot P_1 (x_i - 1, y_i) \\
&\quad +\sqrt{2} \cdot P_1 (x_i + 1 + y_i) \\
&\quad -P_1 (x_i - 1, y_i - 1) \\
&\quad +P_1 (x_i + 1 + y_i - 1) \qquad (1\text{-}3).
\end{aligned}
$$

$$
\begin{aligned}
g_y &= P_2 (x_i, y_i) \\
&= P_1 (x_i - 1, y_i + 1) \\
&\quad +\sqrt{2} \cdot P_1 (x_i + y_i + 1) \\
&\quad +P_1 (x_i + 1, y_i + 1) \\
&\quad -P_1 (x_i - 1 + y_i - 1) \\
&\quad -\sqrt{2} \cdot P_1 (x_i, y_i - 1) \\
&\quad -P_1 (x_i + 1 + y_i - 1) \qquad (1\text{-}4).
\end{aligned}
$$

The direction of the edge is given by the following formula (1-5):-

$$\theta = \arctan (g_y/g_x) \qquad (1\text{-}5).$$

Here, g is determined by the formula (1-1) or (1-2), and is compared with a predetermined reference value g_r, and edge points above the reference value g_r are not kept.

To reduce the number of discarded edge points one could set the reference value g_r to be a large value, but if the reference value g_r is set to be too large a value, then inherently necessary edge points are likely to be discarded, and therefore it is important to set the value g_r to be rather low. It is preferable to set the reference value g_r so as to leave about 80% of all the edge points. It may be set so that about 80% of the edge points remain after the dispersion of g of all the edge points is determined.

Thus, when the somewhat small value of g_r is used and the perceptual grouping is then made, a weak but significant edge point can be extracted without being influenced by noise or the like. This is one of the advantageous features of this embodiment.

The second step will now be explained with reference to Figures 12 to 19.

First of all, as shown in Figure 12, the output picture image P_2 (x_i,y_i) obtained in the first step is divided into small squares of about 8 x 8 pixels and is converted in a modified Hough manner. Where an original picture image consists of 512 x 512 pixels, it will be divided into 64 x 64 picture images. Thus, in this embodiment, it is divided into small squares of 8 x 8 pixels by way of example, but, depending on the required precision, it may be divided into 4 x 4 pixels, or other values as desired.

An output picture image P_2 (x_i,y_i) and a selected small square of 8 x 8 pixels are shown respectively in Figures 12 and 13. As shown in Figure 14, if a small square of from 4 x 4 to 16 x 16 pixels is selected, through which the fold passes, the short length of fold within the small square can be considered as a substantially straight line.

First of all, we should briefly explain the modified Hough conversion.

Figure 13 is a simplified representation of a common, well used x,y coordinate system. In order to make a modified Hough conversion, then as shown in Figure 15, addresses are attached all round the outer periphery of the small square of 8 x 8 pixels.

Then, the straight line on the small square of 8 x 8 pixels can be defined by designating a start address (S) and end address (E). For example, the straight line represented by a broken line in Figure 15 can be defined as a straight line having a start address 3 and an end address 20.

On the other hand, the kinds of straight lines which can be described on the small square of 8 x 8 pixels are (32 x 32)/2 = 512. The reason for multiplying (32 x 32) by 1/2 is that the straight line on the small square is not a vector. That is to say, the straight line between the start address 3 and end address 20 can be considered to be identical to the straight line between the start address 20 and end address 3.

Therefore, all the straight lines correspond to one of the elements as arranged in Figure 16.

When any edge points on the straight line corresponding to one arrangement on the arranged elements are present within any one of the arranged elements, for example, considering the straight line shown as a broken line in Figure 15, a straight line having a start address 3 and an end address 20, it passes through four small squares having four edge points, and the line will therefore be expressed as in Figure 16.

If a modified Hough transformation in accordance with such an idea, in fact, a result such as is shown in Figure 17 will be

obtained. As already described, one of the arranged elements (one of the squares in Figure 17) corresponds to one straight line and the numeral (vote) within the arranged element represents the number of edge points existing on that straight line.

The larger the number of edge points existing on any straight line, the higher is the possibility that this is in fact the required straight line.

Therefore, about 5 votes are extracted as contour segment candidates from the larger number of votes. Such extracted contour candidates bears a mark O in Figure 17 and are shown as a table in Figure 18.

Here lies an idea of extracting the largest number of votes and making it a required contour segment. However, if it is made so, a wrong contour segment is likely to be extracted, for example, as in the case shown in Figure 19 in which (a) is a contour segment to be extracted, whereas, if judged only by the number of votes, the contour segment (b) will be erroneously extracted because of noise content.

In order to avoid such danger, the number of votes is reduced to about 5 arranged elements, any constant grouping is then identified, and the optimum contour segment can then be extracted.

The perceptual grouping of the third step will now be explained with reference to Figures 20 to 23.

In this embodiment, the perceptual grouping is made by noting the three items defined below. However, in addition to the under-mentioned three items, the size of the gradient (edge magnitude) may be noted, or the colour may be noted. The items are:-

1. Edge orientation
   (on edge points):
   Reference: $\pm 22.5^{\circ}$
2. Grey level
   (on pixels):
   Reference: $\pm$ 4 level
3. Continuity
   (on edge points):
   Reference: $\pm$ 1 pixel distance

Each of the above-mentioned three items will now be explained.

For example, in the case of Figure 17, the following processes are made on each of the five lines in Figure 17:-

<u>1. Edge orientation:-</u>

For example, the line 4, the arranged element (16,4) in Figure 18 has 9 edge points arranged in the order of the smaller edge direction θ determined in the first step, as shown in

Figure 20. A new grouping is made where there is a gap larger than 45°. In the examples shown in Figure 20, the difference of θ between the 8th edge point and 9th edge point is:

$$62° - 35° = 27° \; (> 22.5°).$$

Here, a regrouping is made.

2. Grey level:-

As in the case of the above-mentioned edge orientation, the grey level of the parts corresponding to the edge points are arranged in the order of the smaller one and a grouping is made where the gap of the grey levels is larger than 4.

3. Continuity:-

The x-coordinates and y-coordinatesof the edge points are noted and are arranged in the order of the smaller x-coordinate as shown in Figure 21. The same x-coordinates are arranged in the order of the larger y-coordinate. Where the difference Δx of the x-coordinate is $\Delta x > 1$ or the difference Δy of the y-coordinate is $\Delta y > 1$, a grouping is made. In the example shown in Figure 21, the difference of the y-coordinate between the 4th edge point and 5th edge point is 2 and here a grouping is made. Thus, by noting both of the x-coordinate and y-coordinate, even if the straight line rises extremely or lies level with respect to the x-axis or y-axis, the discontinuous point can be positively extracted and a grouping can be made. For example, in Figure 22, the respective edge points in the example in Figure 21 are plotted on the x and y-coordinates. In such a case, if only the x-coordinate is noted, it is not possible to detect that the straight line is discontinuous.

By making the above three operations, generally such results, as are shown for example in Figure 23, are obtained.

Here, for example, if a logical formula of:-

Continuity $\cap$ (Grey Level) $\cap$ (Edge Orientation) (1)

is applied as a condition of extracting the optimum contour segment, as shown in Figure 23, the edge points can be grouped in six groups of A to F. In the example in Figure 23, the group A has the most edge points and the number of the edge points is 6.

The condition of extracting the optimum contour segment is

not limited to the logical formula (1) but the following logical formula (2) may be used, for example:-

Continuity $\cap$ (Grey Level $\cup$ Edge Orientation) (2).

The same is carried out also on the other arranged elements and the group having the most edge points among them is extracted and forms a contour segment to be extracted in the small square of 8 x 8 pixels. Thus, in the third step, a contour segment of 64 x 64 small regions consisting of 8 x 8 pixels could be extracted. (Needless to say, there are many small regions in which no contour segment exists). The division into small regions gives advantages, in that parallel processes by a plurality of computers are possible and the operating time can be reduced. Parallel processes may be made by using a plurality of exclusive IC's.

Furthermore, also in the case of noting the size of the gradient (edge magnitude) or the colour, in the same manner, the edge points may be arranged in the order of the size of the gradient or the colour and may be grouped where there is a gap larger than that predetermined.

The fourth step will now be explained with reference to Figures 24 to 26.

In this fourth step, the contour segments obtained in the third step are connected. This is called a tracing or connecting of edges.

In tracing the edges, that segment from which the tracing is to be started is important. In this embodiment, a pyramid quad tree structure is utilised to trace the edges. A step of obtaining a curve of a fold by utilising this pyramid quad tree structure will now be explained with reference to Figures 24 and 25.

First of all, as shown in Figure 24, a pyramid quad tree structure is made by making a small region, consisting of 8 x 8 pixels, a leaf node (or leaf). That is to say, in the step S41 shown in Figure 25, a small region of 8 x 8 pixels is made a leaf node and, in the step S42, the sum of the contour segment numbers of four children nodes is made a contour segment number of a parent node to obtain a picture image of n/2 x n/2 pixels. Then, through the step S43 of judging whether the number of pixels is 1 or not, the step S42 is repeated until a root (or root node) is reached. In the thus made pyramid quad tree structure, the parent node retains the number of the contour segments of the children nodes. In Figure 24 the figures near the respective nodes represent the numbers of contour segments.

Then, in order to discover a starting contour segment, the tree is searched downward from the root, that is to say, in the step S44, the operation of selecting that child node having the

most contour segments among the four son modes is repeated. As shown in Figure 24, in the stage of the leaf, in a case where a plurality of leaves having contour segments exist, any contour segment may be made a starting contour segment.

Then, in the step S45, the contour segment determined in the step S44 is made a starting contour segment and the contour segments are connected.

The operation of connecting these contour segments will now be explained with reference to Figures 26(a) to (d).

As shown in Figure 26(a), in case the contour segments are connected in the order of the small regions 1 and 2, the next searching direction will be the direction indicated by the arrow in the drawing. Therefore, in this case, the small regions a, b and c are checked.

In the same manner, as shown in Figure 26(b), in case the contour segments are connected in the order of the small regions 1 and 2, the next searching direction will be the direction indicated by the arrow in the drawing. In this case, the small regions a, b and c are checked.

As shown in Figure 26(c), in case the contour segments are connected in the order of the small regions 1 and 2, the small regions a, b and c are checked but, in case the contour segments exist in both of the small regions a and c, the directions of the contour segments a and c are checked and the direction in which a smooth connection is made is selected. In the case of Figure 26(c), the contour segment of the small region c is selected.

As shown in Figure 26(d), in case the contour segments are connected in the order of the small regions 1 and 2 and no contour segment exists in the small regions a, b and c, the small regions d, e, f, g, h, i and j are inspected, because, in case the contour segment a is considered to have lapsed for any reason, the next search will be of d, e and f, in the same manner, in case the contour segment b is considered to have lapsed, the next search will be of f, g and h and, in case the contour segment c is considered to have lapsed, the next search will be of h, i and j.

In case the contour segments are to be connected, the angle formed by two contour segments to be connected may be limited to be within $\pm 45^{o}$.

Whenever the contour segments are connected, the numerical value on the quad tree will be corrected. That is to say, the

value of the leaf corresponding to the connected contour segment will be changed from 1 to 0. The value of the parent node above it will also be corrected.

The contour segments are connected in both directions.

When a curve is thus obtained, in the step S46, whether the fourth step is to be concluded or not is judged and, in case it is not be be concluded, when the steps in and after the step S41 are again repeated, another curve can be obtained.

The fifth step shall be explained in the following with reference to Figures 27 to 31.

In the fifth step, the insertion direction is judged and determined by the form of the fold determined in the fourth step.

The form of the fold to be determined is of such pattern as is shown, for example, in Figures 27(a) to (d). The insertion direction is determined respectively by the methods explained in the following.

Figure 27(a) shows the case that two curves (folds) C, C_1 and C_2, having an intersection (or branching point) indicated by the mark * in the drawing are obtained. In this case, by judging the direction of the contour segment at the point indicated by the mark * in the drawing, the inner fold is judged. In the case of Figure 27(a), the curve C_2 is inner and the centre (point a) of the inner curve is made an insertion direction. In a case where such a curve is obtained, it is considered to be a case where such a tube cavity of the large intestine in which an endoscope is inserted is curved, and the inner fold is partly hidden.

In the method shown in Figure 27(b), radial lines are constructed respectively at about five points on the obtained curve and the part in which the intersections of the radial lines concentrate is made the insertion direction.

In the method shown in Figure 27(d), in any case where the obtained curve is broken anywhere, the nearest curves are connected and the centre of gravity of the obtained ring is made an insertion direction.

In the methods shown in Figures 27(b) to (d), any curves or rings may be used, the largest curve or ring may be used or the ring n-th from a large ring may be predetermined to be used.

The centre of gravity can be determined by such a process as is shown, for example, in Figure 28.

First of all, in the step S51, the number of pixels contained in the circle or ellipse of a fold is determined and is made N as shown in Figure 29. The number of pixels may be replaced with the number of small squares used in the step.

Then, in the step S52, as indicated by the arrows in Figure 30, the number of pixels contained in the circle or ellipse of the fold is counted in the direction of the x-axis from above until the number becomes N/2. The value of the y-coordinate when the number becomes N/2 is represented by y_0 which is a y-coordinate of the determined centre of gravity.

In the same manner, in the step S53, as indicated by the arrows in Figure 31, the number of pixels contained in the circle or ellipse of a fold is counted in the direction of the y-axis from the left side until the number N/2. The value of the x-coordinate when the number becomes N/2 is represented by x_0 which is an x-coordinate of the determined centre of gravity.

Then, in the step S54, the centre of gravity of the fold is determined as (x_0,y_0). The form of the fold has been described as circular or elliptical, but is not limited to such shapes.

As the endoscope is inserted, the form of the fold will vary. Therefore, the centre of gravity of the fold n-th as counted from a large one may always be determined and may be judged to be an insertion direction or an average value of the centre of gravity

of the n-th fold as counted from a large one and the centre of gravity of the n + m-th fold may be determined and judged to be an insertion direction. Also, the centre of gravity of the fold on the innermost side may be made an insertion direction. The direction in which the most centres of gravity among the centres of gravity of a plurality of folds are located may be made an insertion direction.

As shown in Figure 4, in a case where the large intestine 20 is curved, then as shown in Figure 5, the centre of gravity of the fold is different depending on the fold. In the case of Figure 5, the more the centre of gravity is on the inside of the fold, the more the insertion direction side is on the upper side. The larger the curvature, the larger the displacement of this centre of gravity. Therefore, the curvature of the large intestine 20 can be detected from the displacements of the centre of gravity of a plurality of folds.

Thus, according to this embodiment, the form of a fold is determined by the first to fourth steps, the endoscope insertion direction is judged in the fifth step on the basis of the form of the fold and thereby the endoscope insertion direction can be simply detected.

In the case of extracting a discontinuous point (edge point) in the endoscope picture by the first step, when the reference value is set to be rather low and the value of the gradient g is left to be small to some extent, a necessary discontinuous point (edge point) will be able to be extracted without being influenced by noise or the like.

In cases where contour segment candidates are extracted by utilising a modified Hough conversion in the second step or in cases where the optimum contour segment is extracted from the respective divided picture images by a perceptual grouping in the second step, then by dividing the endoscope picture image into small regions, parallel processing by a plurality of computers is made possible and the operating time can be reduced.

As a pyramid quad tree structure is utilised in extracting a starting contour segment in the fourth step, the processing time can be remarkably reduced.

Incidentally, in this embodiment, a grey level is noted in extracting discontinuous points in the first step, but a colour may equally be noted, as described above.

In case a colour is noted, for example, the variation rates of the hue and saturation may be inspected and the hue and saturation as varying may be extracted.

For example, in case three primary colour components (three exciting values) R, G and B of a CIE-RGB colouring system are obtained from an original picture, a hue O can be represented by a formula (2-2), by using the following formula (2-1):-

$$\theta_1 = \cos^{-1} \frac{2r - g - b}{\sqrt{6}\,\{(r-1/3)^2 + (g-1/3)^2 + (b-1/3)^2\}} \tag{2-1}$$

$$\theta = \theta_1 \ (g \geq b), \quad \theta = 2\pi - \theta_1 \ (g < b) \tag{2-2}$$

where: $r = R/(R + G + B)$;

$g = G/(R + G + B)$; and

$b = B/(R + G + B)$.

The saturation S can be represented by the following formula (2-3):-

$$S = 1 - 3 \min (r, g, b) \tag{2-3}$$

where min (r, g, b) represents the minimum value of r, g and b.

Thus, when the hue and saturation are made numerical values for respective pixels of the original picture, then just as in the case of noting the grey level, by a spatial filtering or the like, the hue and saturation variations can be extracted. Just as in the case of noting a grey level, by carrying out the second to fifth steps, the fold can be extracted by noting the colour.

In a case where the original picture is given by an NTSC signal, the hue can be obtained from the phase of a chrominance signal and the saturation can be obtained from the amplitude of the chrominance signal.

Also, the value of a specific colour component may be noted.

In Figures 32 to 34, the second embodiment of the present invention is shown.

In this embodiment, as compared with the first embodiment, the fourth step, that is the step of connecting contour segments is different.

In this embodiment, a plurality of contour segments are simultaneously connected by using an overlapped pyramid.

The overlapped pyramid structure used in this embodiment is shown in Figure 32. In this overlapped pyramid, respective nodes have 16 children nodes and 4 parent nodes. In Figure 32, 4 x 4 (=16) nodes enclosed with fine solid state lines belong to

one parent node. That is to say, children nodes corresponding to a plurality of parent nodes are overlapped. Thus, one child node has 4 parent nodes. Such an overlapped pyramid structure is made by considering a small region consisting of 8 x 8 pixels as a leaf node.

Then, by using this overlapped pyramid structure, a method of connecting contour segments will be explained.

In Figure 33, one parent node and 16 children nodes corresponding to the parent node in Figure 32 are parted and shown.

First of all, in case there are a plurality of line segments in a region consisting of 2 x 2 (=4) nodes enclosed with thick solid lines among 16 children nodes in Figures 32 and 33, it will be examined whether these segments can be connected. Here, the directions and edge points of two contour segments (which are hereinafter called connecting information) are considered to determine whether the two contour segments are connected. For example, if the difference of the direction between two contour segments is 45° or less, and also the distance between the edge points is a predetermined distance threshold D_{max} or less, two contour segments are considered to be connected.

In Figure 33, two sets of contour segments connected in accordance with the above mentioned rule are shown. In the example shown in this Figure, there are contour segments (a), (b), (c) and (d) within the respective 2 x 2 nodes. Since the difference in direction θ_1 between contour segments (a) and (b) is 45° or less and also the distance D_1 between edge points is a distance threshold D_{max} or less, they are considered to be connected as

the same group. Similarly, since the difference in direction θ_2 between the two contour segments (c) and (d) is 45^o or less, and also the distance D_2 between edge points is a distance threshold D_{max} or less, they are considered to be connected as the same group.

The coordinates (Y_3, Y_4, Y_5 and Y_6 in Figure 33) of the edge points at which the two sets of lines connected in this manner meet the perimeter enclosing 4 children nodes (shown by thick solid lines), and the angles (θ_3, θ_4, θ_5 and θ_6 in Figure 33) at which the two sets of lines intersect the perimeter, are raised to a parent node as connecting information of the parent node.

Then, a plane to which the above mentioned parent node belongs is considered. That is, 4 parent nodes as shown in Figure 32 have the connecting information raised from their children nodes, respectively. In the regions consisting of these 4 parent nodes, contour segments are connected in accordance with the above mentioned rule.

The same is repeated up to the root level and the whole connection of contour segments is completed.

The above mentioned operation will be explained by using a flow chart in Figure 34.

First of all, a small region consisting of 8 x 8 pixels is made a leaf node in step S61.

Then, in step S62, the coordinates of the points at which contour segments in respective nodes meet the perimeters of the nodes,

and the angles at which the contour segments and the perimeters intersect, are made connecting information.

Next in step S63, when there are a plurality of contour segments in a region of 2 x 2 nodes and when the connecting information satisfies predetermined conditions, that is to say, when the difference in direction between two contour segments is 45° or less, and also the distance between edge points is a predetermined distance threshold D_{max} or less, contour segments are connected.

Next, in step S64, a plane consisting of parent nodes having 4 x 4 overlapped children nodes is formed, and the coordinates of the points at which contour segments connected between 2 x 2 children nodes of the central part among 4 x 4 children nodes meet perimeters enclosing 2 x 2 children nodes (corresponding to a perimeter of a parent node), and the angles at which the contour segments and the perimeters intersect, are made the connecting information in the parent node.

Then in step S65, it is judged whether the number of nodes is one or not. If not, the process goes back to the above mentioned step S63 and steps S64 and S65 are carried out in the level of parent node. If the number of nodes is one, the process is completed.

Thus, the formation of the overlapped pyramid and the connection of contour segments are carried out in parallel. The formation starts from a leaf level and when the root level is reached, the whole contour segments are connected.

The fourth step of the first embodiment is a method including the following steps. A fold is extracted by connecting contour segments one by one and the remaining contour segments are connected one by one in order to extract the next fold. However, in the fourth step of this embodiment, a plurality of folds are extracted in parallel so that processing time can be shortened.

Also, according to the method of this embodiment, since a pyramid is overlapped and formed, the contour segments on a boundary of a region are not overlooked.

Other information, operation and effects are the same as the first embodiment.

The endoscope operator may insert the endoscope by the curving operation in the endoscope insertion direction detected by the method of the present invention, or the endoscope may be inserted by automatically directing the tip part by using the apparatus in the manner described.

As explained above, according to the present invention, by extracting the form of a fold and using a judgement on the basis of this form of the fold, the endoscope insertion direction can be simply detected.

Also, by dividing an endoscope picture image into small regions in extracting contour segments and by utilising a pyramid quad tree structure in connecting the contour segments, there is an effect of reducing the processing time.

In the case of extracting discontinuous points in an endoscope picture image, by setting the reference value to be rather low, extracting contour segment candidates and then extracting the optimum contour segment by a perceptual grouping, there are the effects that the influence of noise or the like can be reduced, the form of the fold can be extracted more accurately and the insertion direction can be detected.

It is apparent that, in this invention, implementation methods differing over a wide range can be formed without departing from the spirit and scope of the invention. This invention is not restricted by its specific working modes except being limited by the appended Claims.

PATENT CLAIMS:

1. A method of detecting a required endoscope insertion direction including the step of extracting the form of a fold existing on the inside wall of an observed part from an endoscope picture image so that the endoscope insertion direction may be judged on the basis of the form of the fold extracted by said step.

2. A method according to Claim 1, wherein said fold form extracting step is to detect a part at which the brightness or colour of the picture image varies and to consider said part to be a fold.

3. A method of detecting a required endoscope insertion direction comprising the respective steps of:

extracting discontinuous points in an endoscope picture image;

extracting contour segments based on said discontinuous points from respective divided picture images obtained by dividing the picture image obtained by said discontinuous point extracting step into a plurality of picture images;

connecting the contour segments obtained by extracting said contour segments; and

considering the line connected by said connecting step to be the form of a fold existing on the inside wall of an observed part and judging the endoscope insertion direction on the basis of said form of the fold.

4. A method according to Claim 3, wherein said discontinuous point extracting step includes extracting points at which the brightness of the picture image varies.

5. A method according to Claim 3, wherein said step of extracting discontinuous points includes extracting points at which the colour of the picture image varies.

6. A method according to Claim 3, wherein said step of extracting discontinuous points includes extracting discontinuous points by applying a spatial filtering by using an overlapped matrix.

7. A method according to Claim 3, wherein said step of extracting contour segments has a step of extracting contour segment candidates and a step of extracting the optimum contour segment from among the candidates extracted by said candidate extracting step.

8. A method according to Claim 7, wherein said candidate extracting step includes using a modified Hough conversion in extracting the contour segments.

9. A method according to Claim 7, wherein said modified Hough conversion includes defining the contour segments within the divided picture image by addresses attached to the periphery of the divided picture image.

10. A method according to Claim 7, wherein said optimum contour segment extracting step includes carrying out a perceptual grouping to extract the optimum contour segment.

11. A method according to Claim 3, wherein said optimum contour segment extracting step utilises at least an edge orientation, grey level, continuity, edge magnitude or colour in carrying out said perceptual grouping.

12. A method according to Claim 3, wherein said connecting step includes extracting a search starting contour segment by utilising a pyramid quad tree structure in connecting said contour segments.

13. A method according to Claim 3, wherein said connecting step includes determining the next searched divided picture image in response to the arranging direction of the divided picture images having so far connected contour segments.

14. A method according to Claim 3, wherein said connecting step includes limiting the angle formed by two connected contour segments to be within $\pm 45^{\circ}$ in connecting said contour segments.

15. A method according to Claim 3, wherein, in a case where two curves having an intersection are obtained by said connecting step, said endoscope insertion direction judging step includes judging the direction of the contour segment at said intersection, thereby judging which curve is inner and then judging the centre of the inner curve to be the insertion direction.

16. A method according to Claim 3, wherein, in a case where a ring-like line is obtained by said connecting step, said endoscope insertion direction judging step includes judging the centre of gravity of said ring-like line to be the insertion direction.

17. A method according to Claim 3, wherein said endoscope insertion direction judging step includes judging the part in which the intersections of radial lines erected respectively from a plurality of points on the curves obtained by said connecting step concentrate to be the required insertion direction.

18. A method according to Claim 3, wherein, in a case where the curve obtained by said connecting step is like a partly incised ring, said endoscope insertion direction judging step includes connecting the obtained curve at both ends and judging the centre of gravity of the thereby obtained ring to be the insertion direction.

19. A method according to Claim 3, wherein, in a case where the curve obtained by said connecting step is partly broken, said endoscope insertion direction judging step includes connecting the nearest curves and judging the centre of gravity of the obtained ring to be the insertion direction.

20. A method according to Claim 1 or Claim 3, wherein said endoscope picture image is obtained by a television camera fitted to the endoscope eye-piece capable of naked eye observation.

21. A method according to Claim 1 or Claim 3, wherein said endoscope picture image is obtained by an imaging means provided in the endoscope.

22. A method according to Claim 3, wherein said connecting step includes forming a pyramid of picture images making picture images consisting of an assemblage of said divided picture images a bottom layer; and

connecting the contour segments in order from the bottom layer of the pyramid of these images to the root node.

23. A method according to Claim 22, wherein a formation of said pyramid of picture images and connection of contour segments are carried out in parallel in said connecting step.

24. A method according to Claim 23, wherein said connecting step includes connecting two contour segments for which the

coordinates of the point at which the contour segments in respective nodes and perimeters of the nodes meet, and the angles at which the contour segments intersect the perimeters, satisfy predetermined conditions among a plurality of children nodes belonging to a certain parent node in said pyramid of picture images.

25. A method according to Claim 24, wherein said predetermined conditions are that the distance between said points is a predetermined distance or less and also the difference of said angles is a predetermined angle or less.

26. A method according to Claim 24, wherein said pyramid of picture images is formed while the coordinates of the points at which the contour segments connected among a plurality of children nodes and lines corresponding to a perimeter of a parent node meet, and the angles at which the contour segments intersect perimeter lines, are made the connecting information of the parent node.

27. A method according to Claim 22, wherein said pyramid of picture images has an overlapped pyramid structure in which respective children nodes corresponding to different parent nodes are overlapped.

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